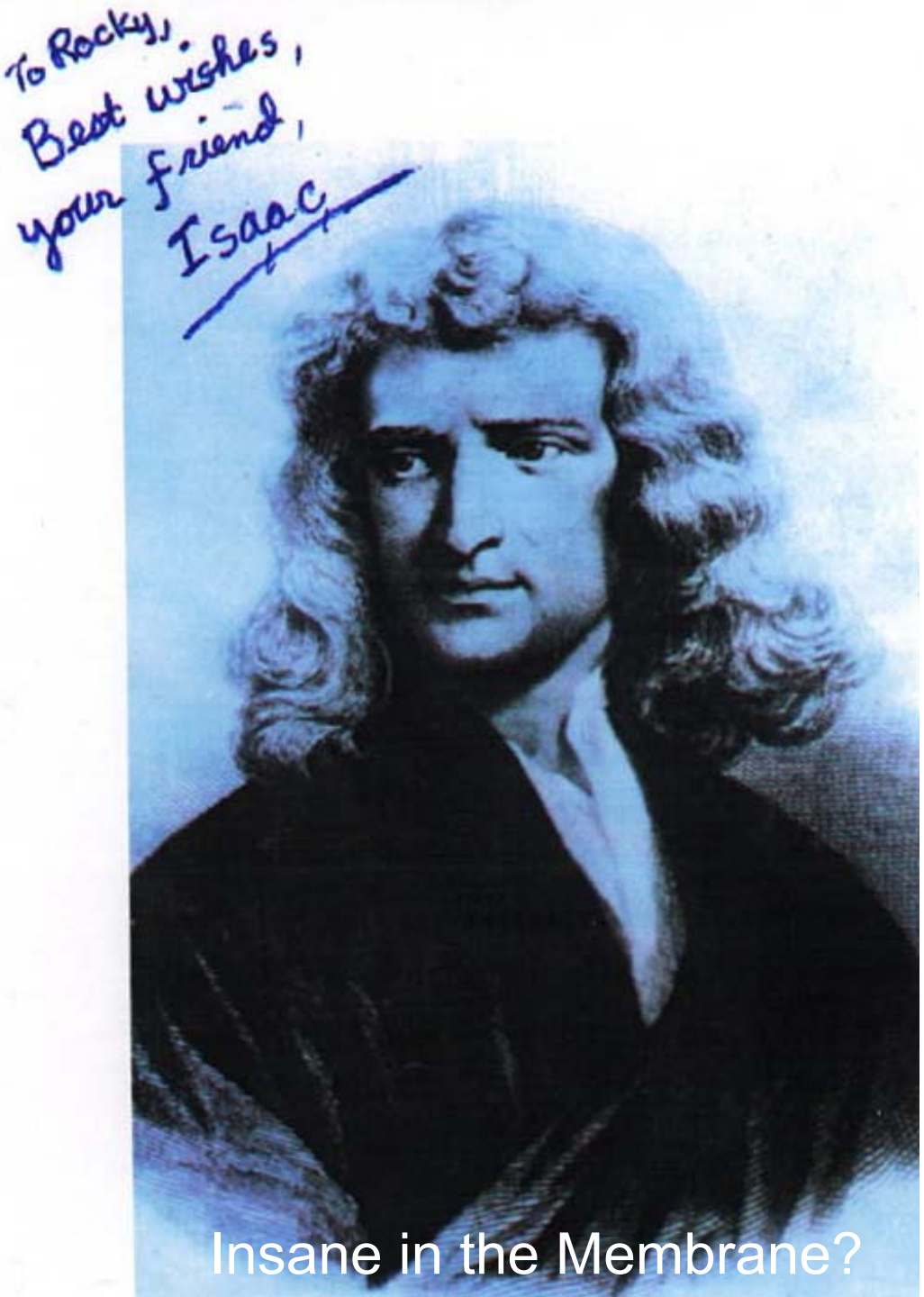


Insane in the Membrane?

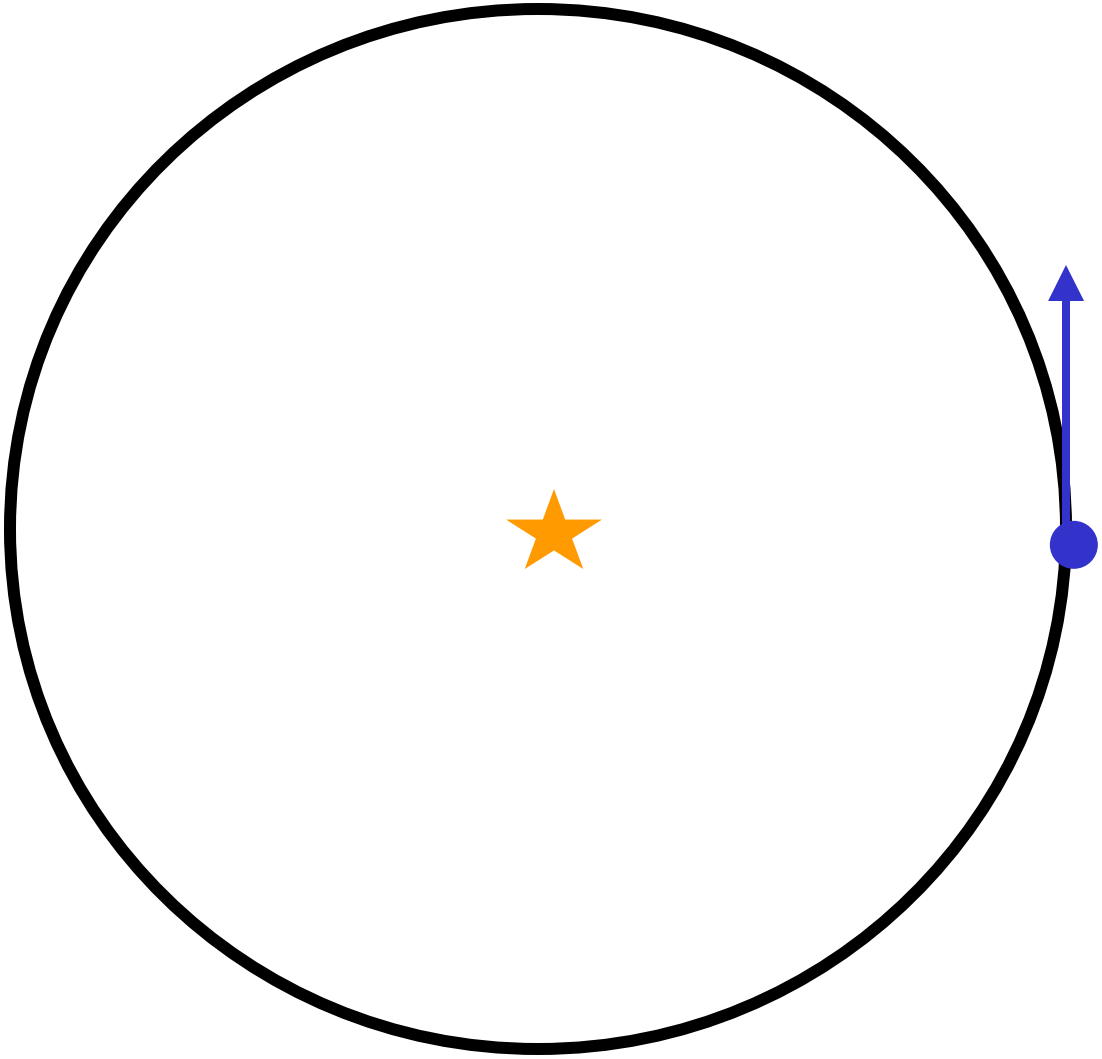
Lecture #4
April 26, 2003

Isaac Newton
1642-1727

Philosophiae Naturalis Principia Mathematica

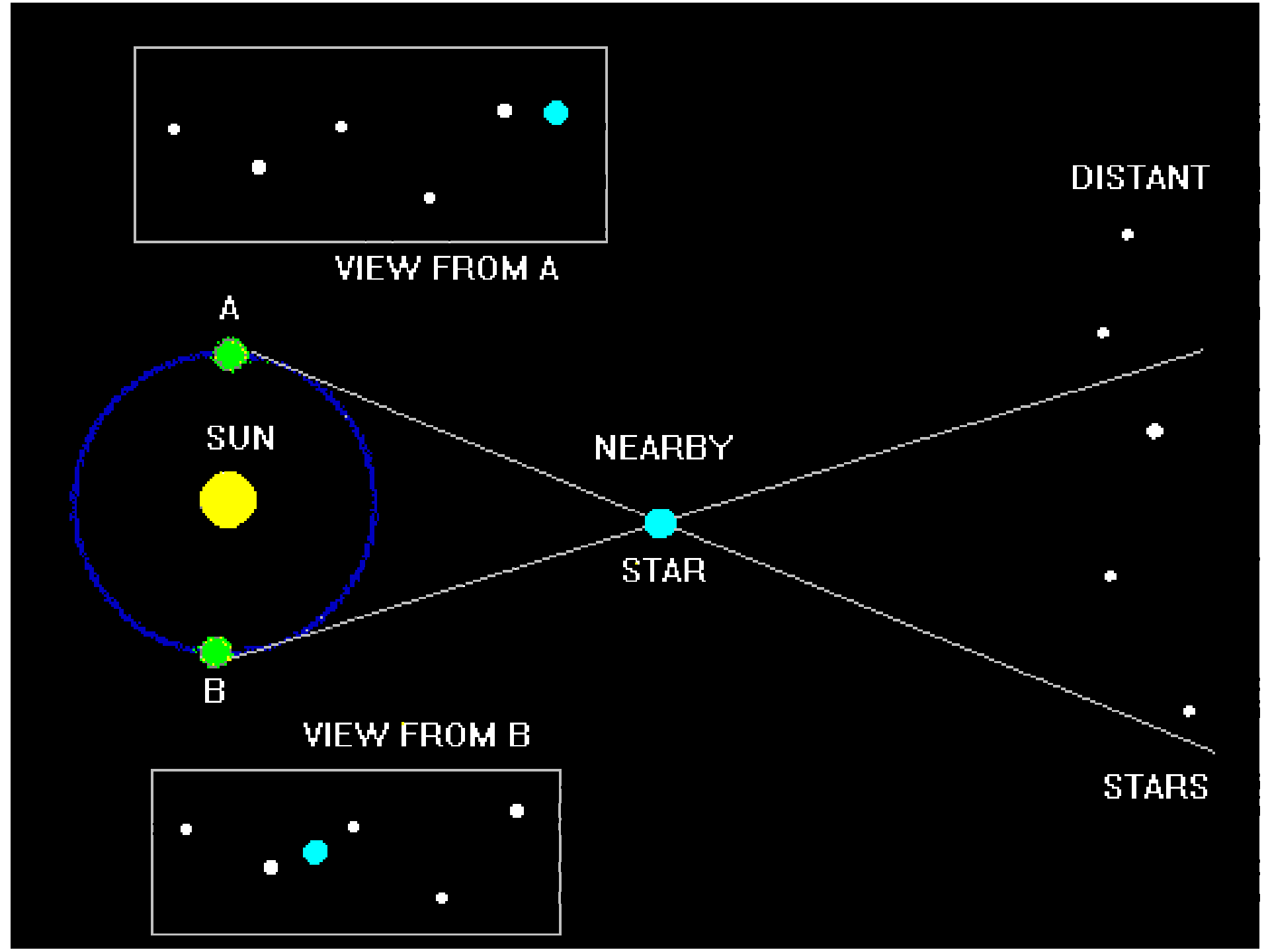
1. Astronomers were doing more than “saving the appearances.”
2. The same laws of physics operate on Earth as in the heavens.
3. The heavens are comprehensible by humans.
4. Crystalline spheres, mechanical gears, and other sundry devices were replaced with a simple mathematical force law.
5. The physics of Aristotle and the astronomy of Ptolemy were relegated to the dust bin.

violent motion
natural motion

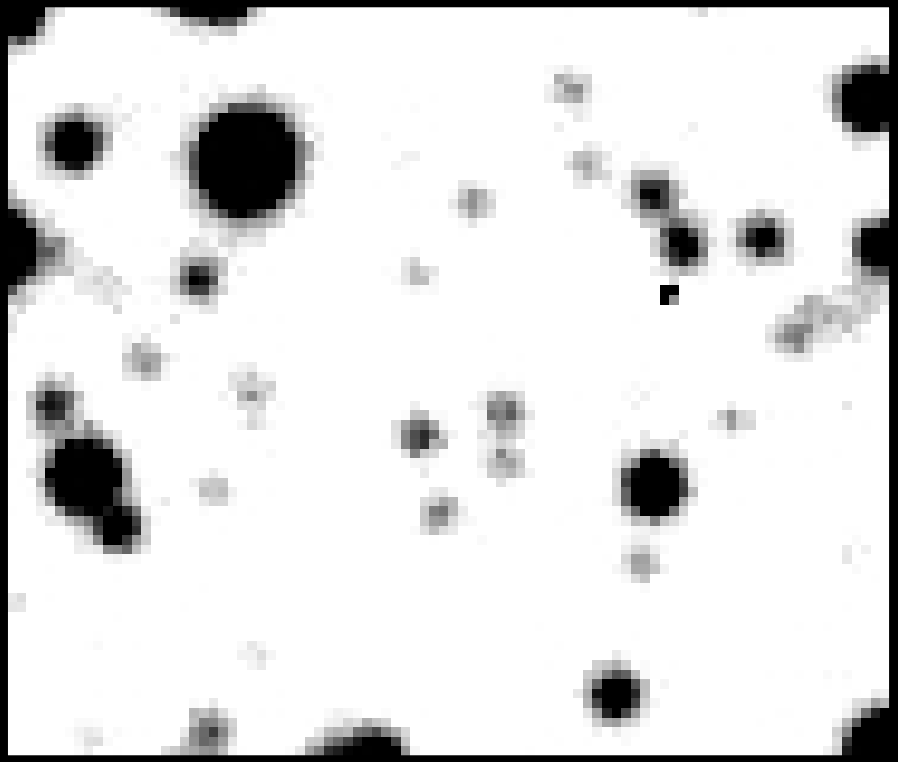


in absence of a force, planet would

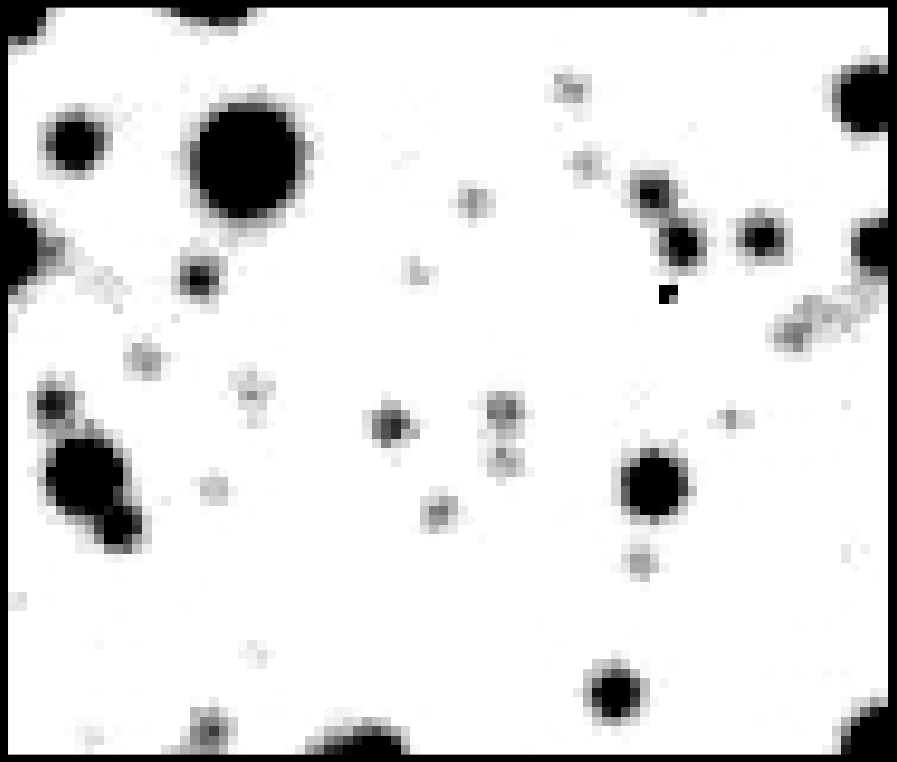
1. slow to a stop?
2. continue to orbit?
3. fly off in a straight line?


VIEW FROM A
DISTANT
A
SUN
NEARBY
STAR
B
VIEW FROM B
STARS

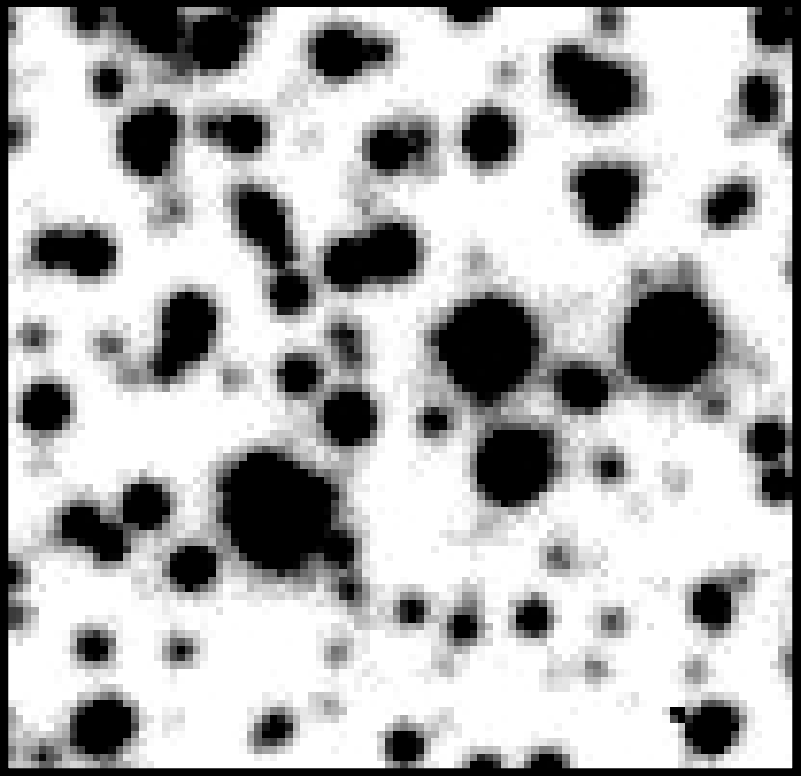
January



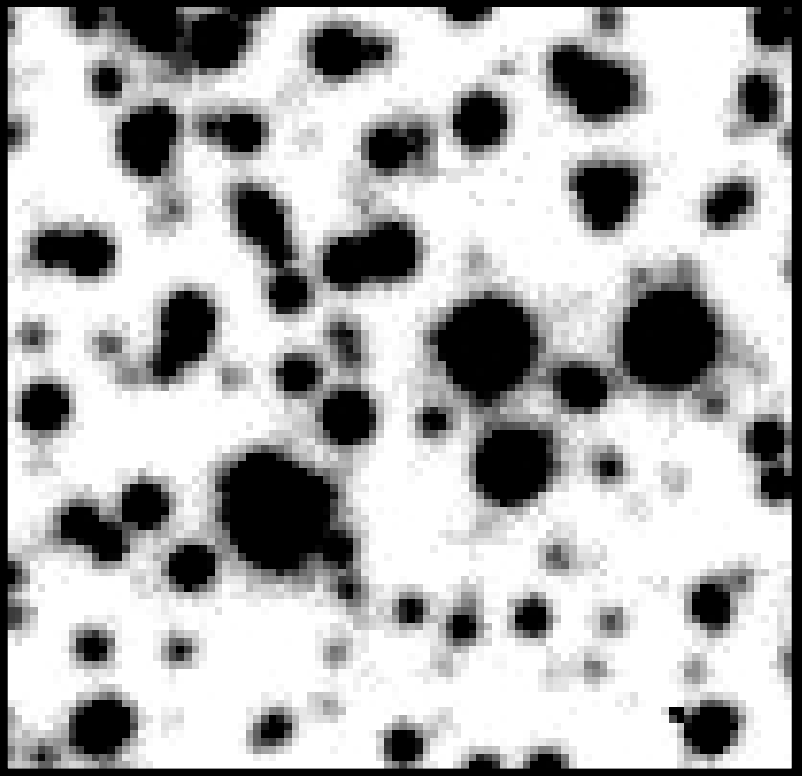
June

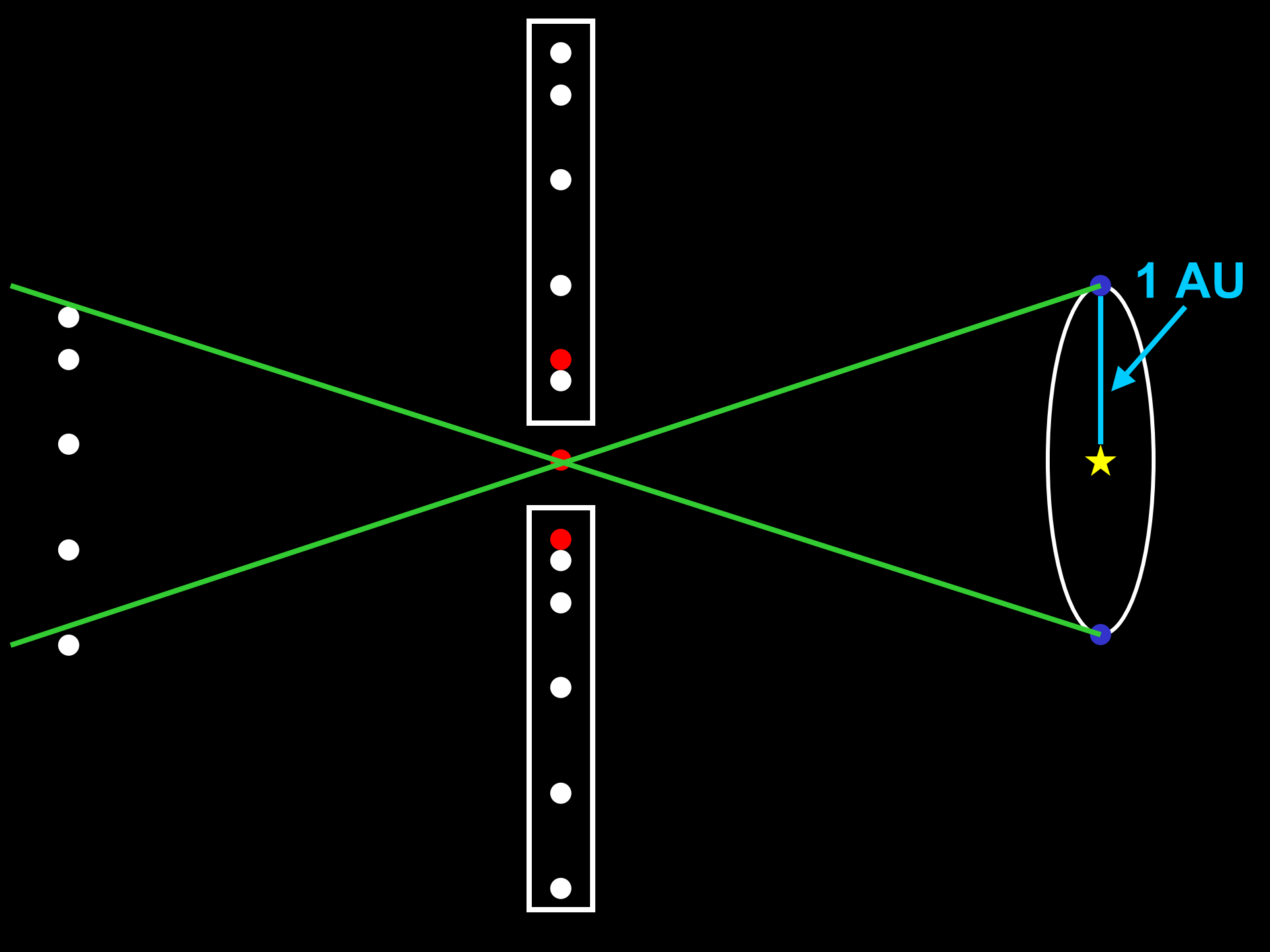


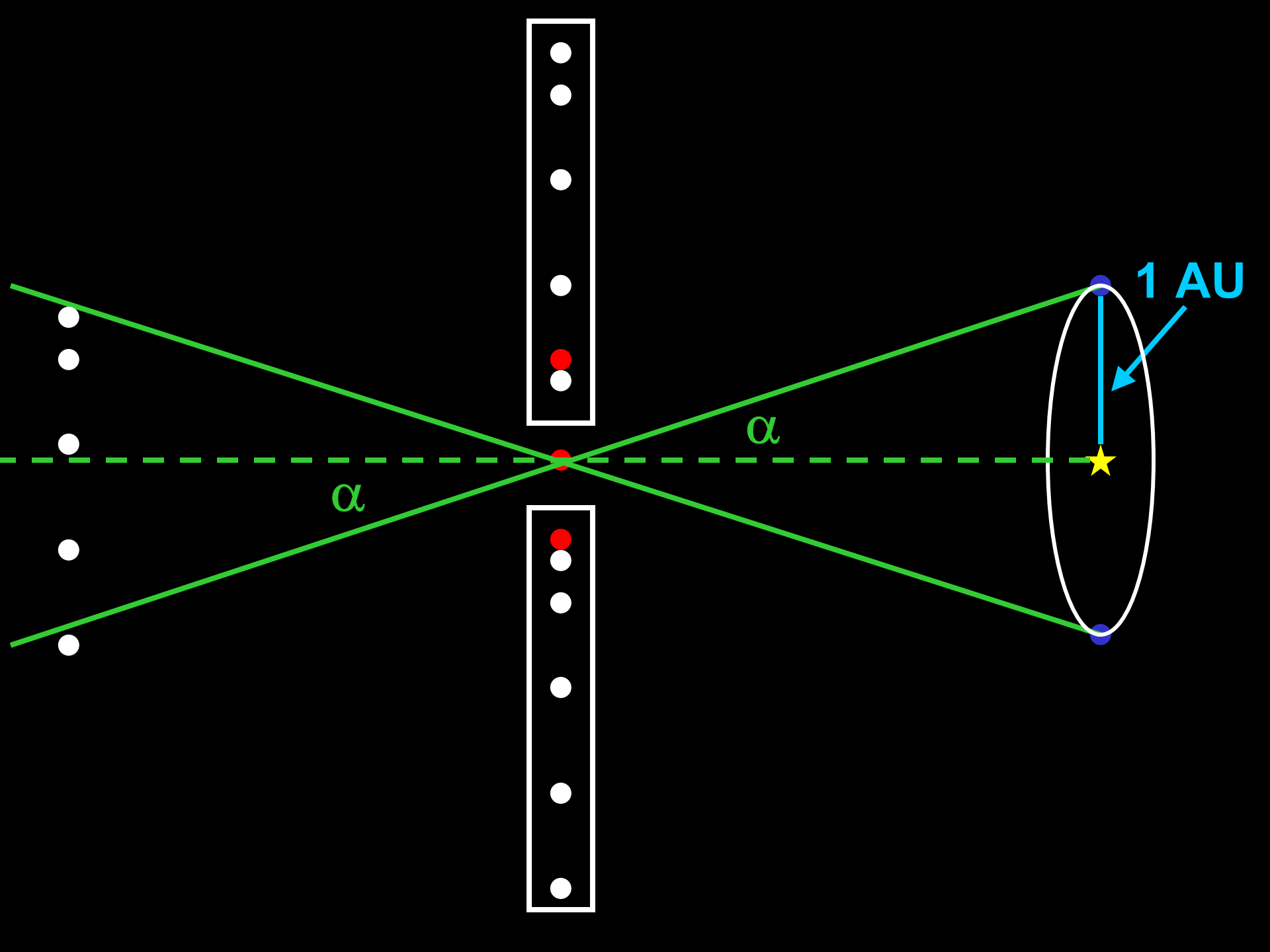
January

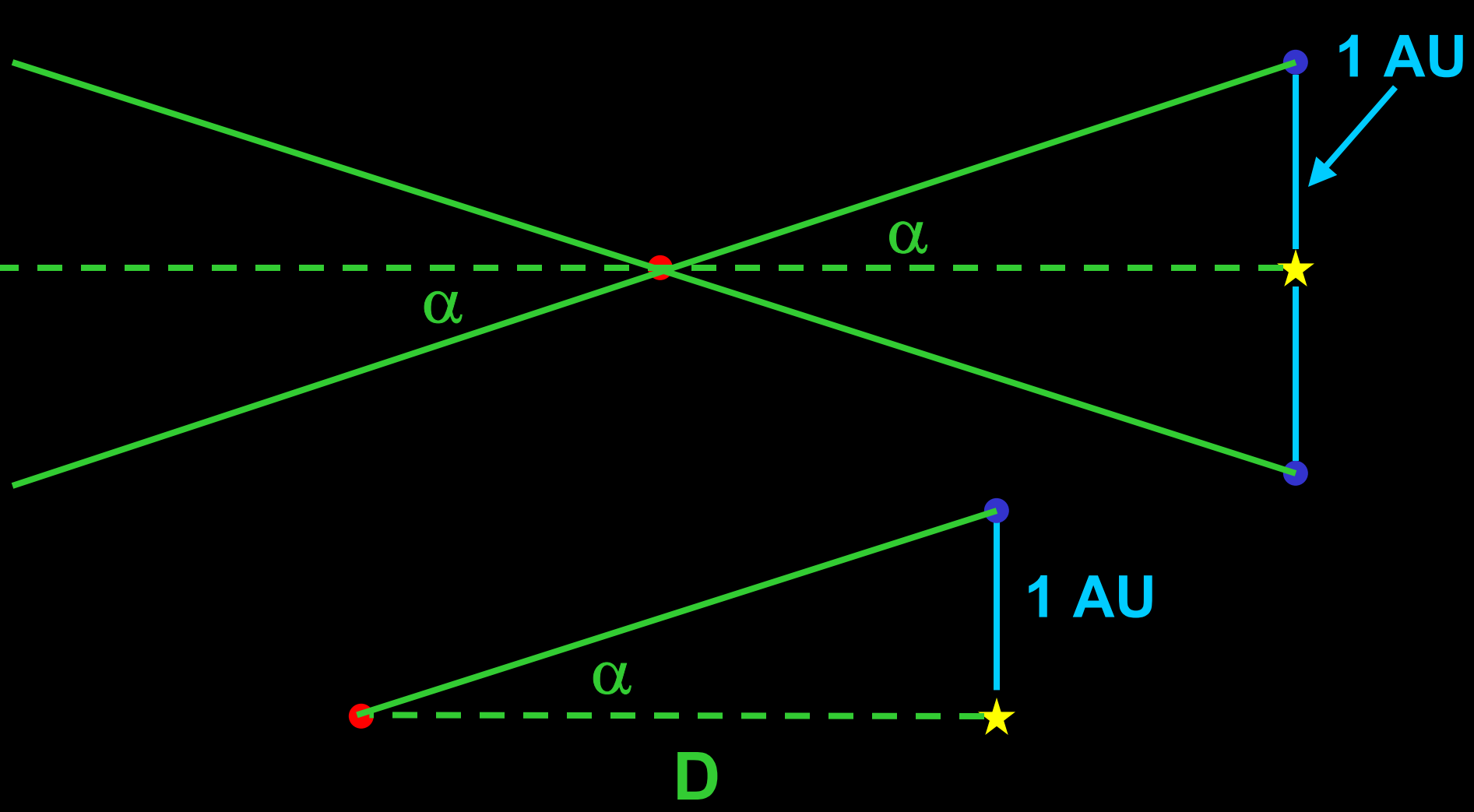


June



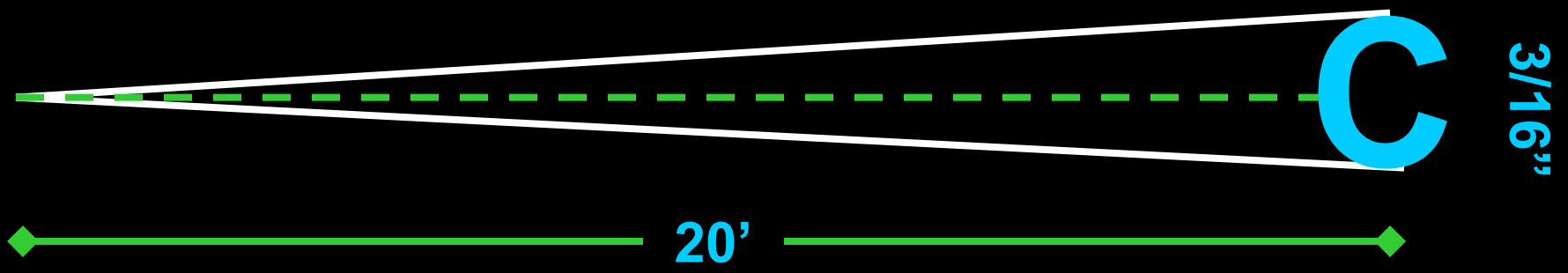

1 AU


1 AU
α
α



$$\tan \alpha = \frac{1\ \text{AU}}{D}$$

How good are your eyes?

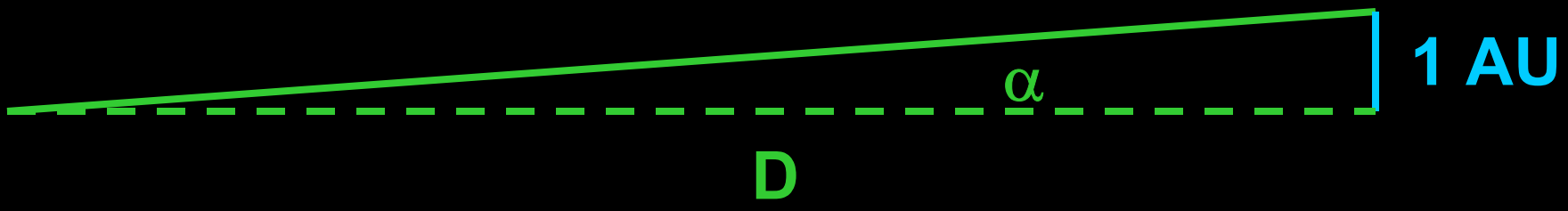


angle = 1/30 of a degree

1 degree = 60 minutes of arc
1 minute of arc = 60 seconds of arc

1/30 of a degree = 2 minutes of arc

resolution of human eye about 1’



$$\alpha = \frac{1\ \text{AU}}{D}\ \text{radians}$$

$$\alpha = \frac{206{,}264.8\ \text{AU}}{D}\ \text{seconds}$$

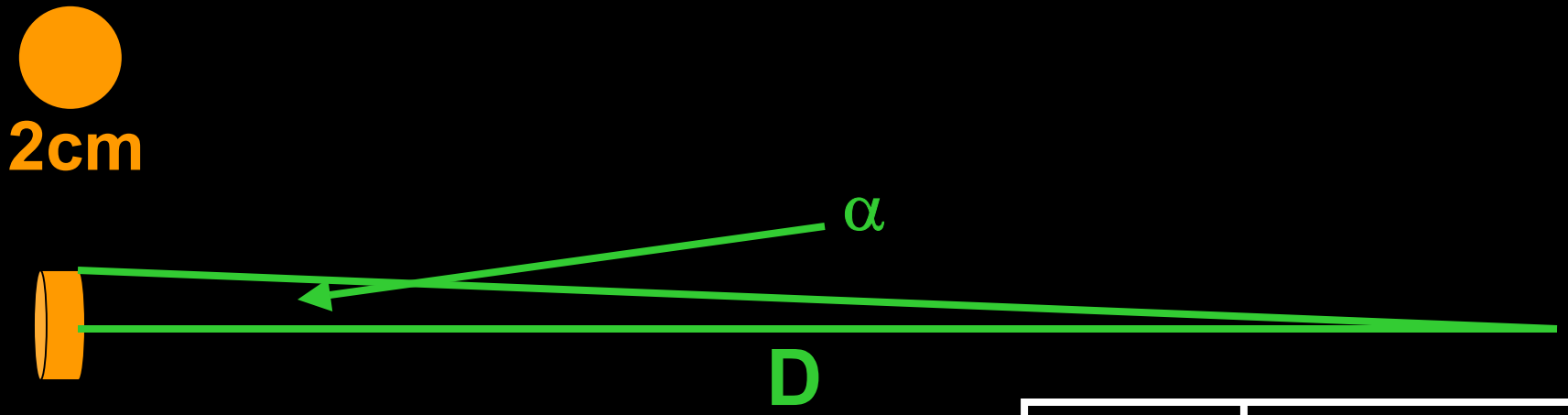
$$\alpha = \frac{1\ \text{pc}}{D}\ \text{seconds}$$

1 pc = 206,264.8 AU = 3.26 light years
= 10^{13} (10,000,000,000,000) miles

$$\frac{d}{pc} = \frac{''}{parallax}$$

star	parallax (”)	distance (pc)
α Centauri	0.75	1.3
Barnard’s star	0.5	2.0
Sirius	0.4	2.5
Altair	0.2	5.0

Let's think for a second of arc



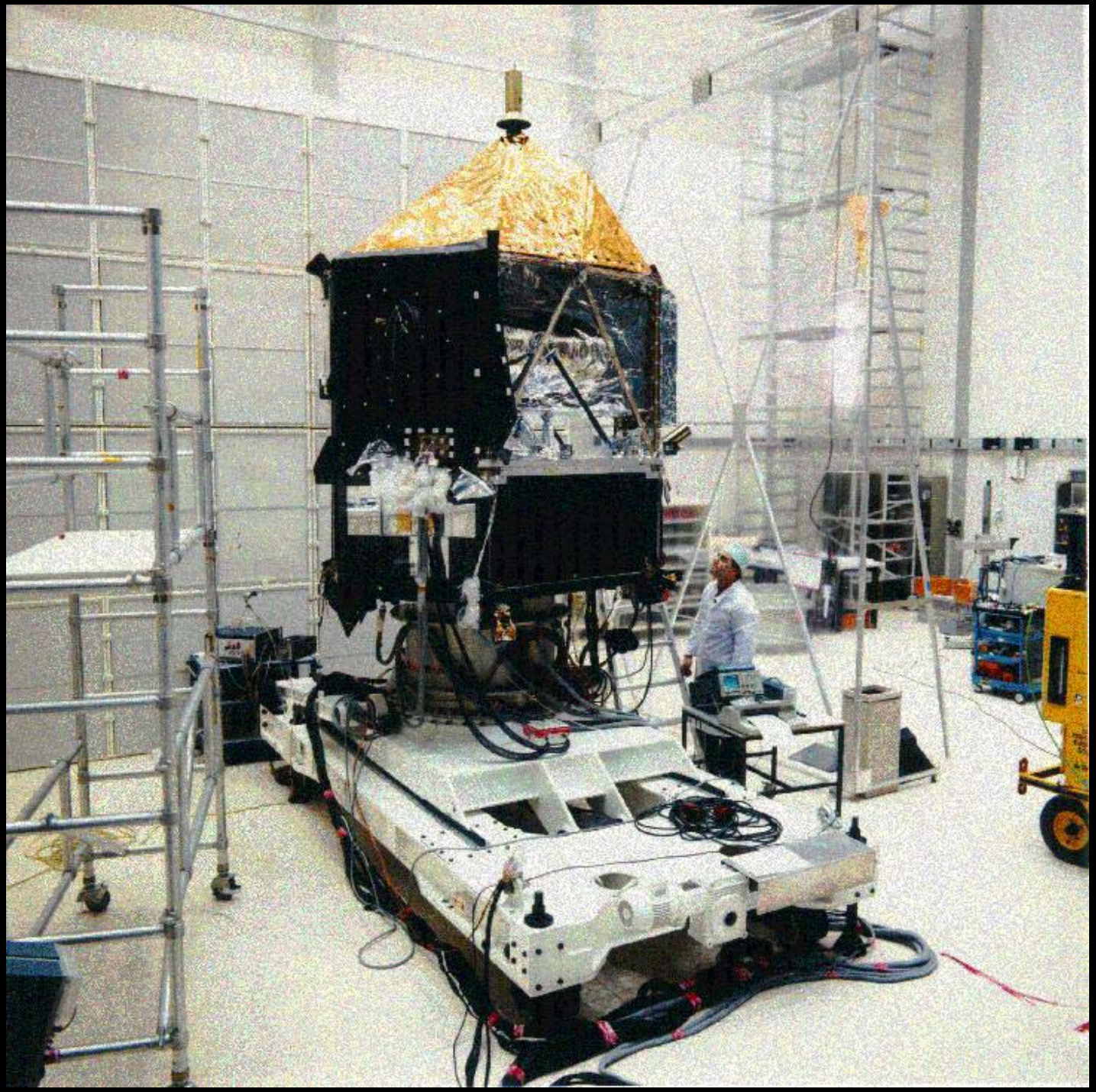
$$\alpha = \frac{1\text{ cm}}{D}\text{ radians}$$

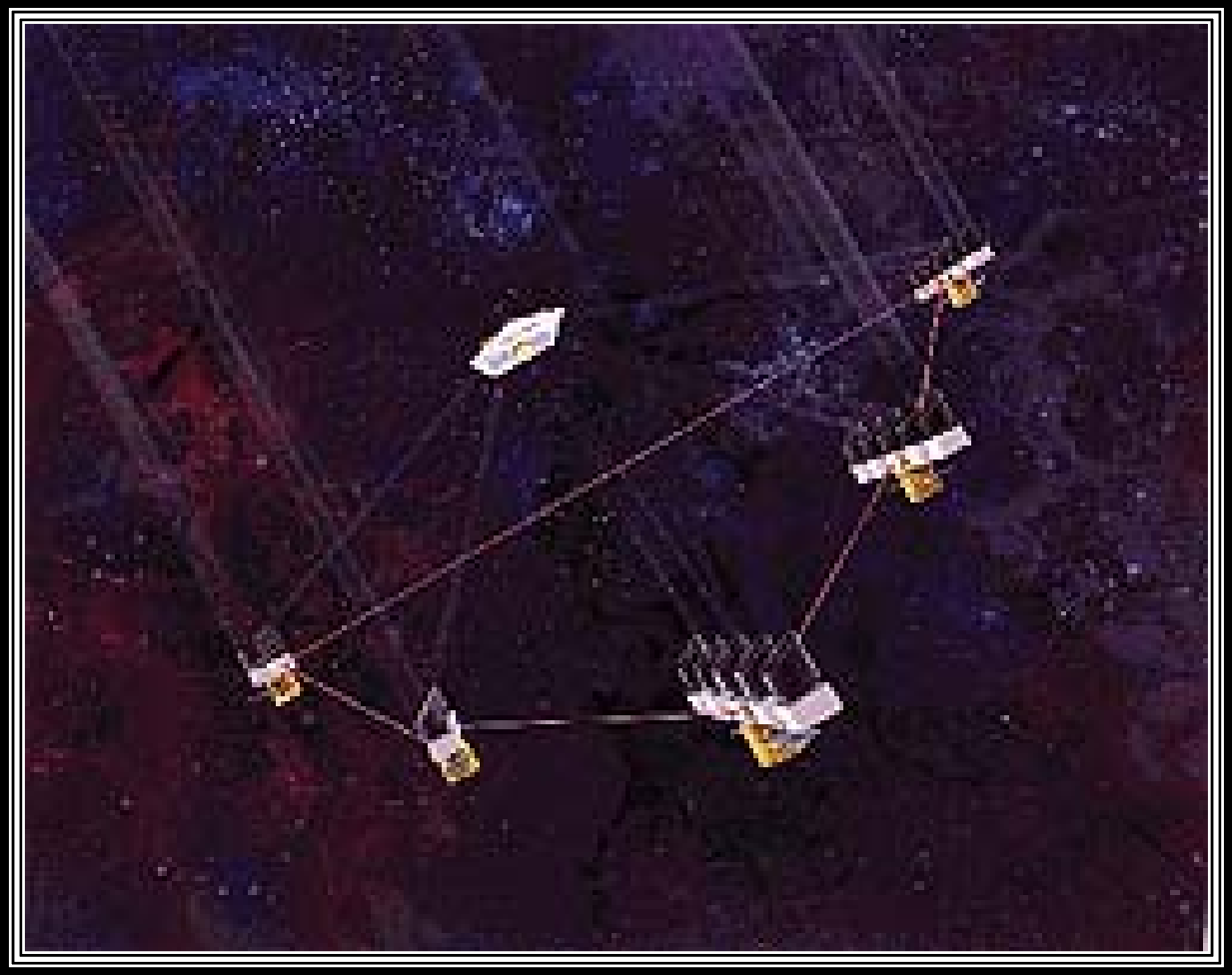
$$\alpha = \frac{200{,}000\text{ cm}}{D}\text{ seconds}$$

$$\alpha = \frac{2\text{ km}}{D}\text{ seconds}$$

α	D
4"	½ km
2"	1 km
1"	2 km
0.1"	20 km
0.01"	200 km
0"	infinity

Hipparcos



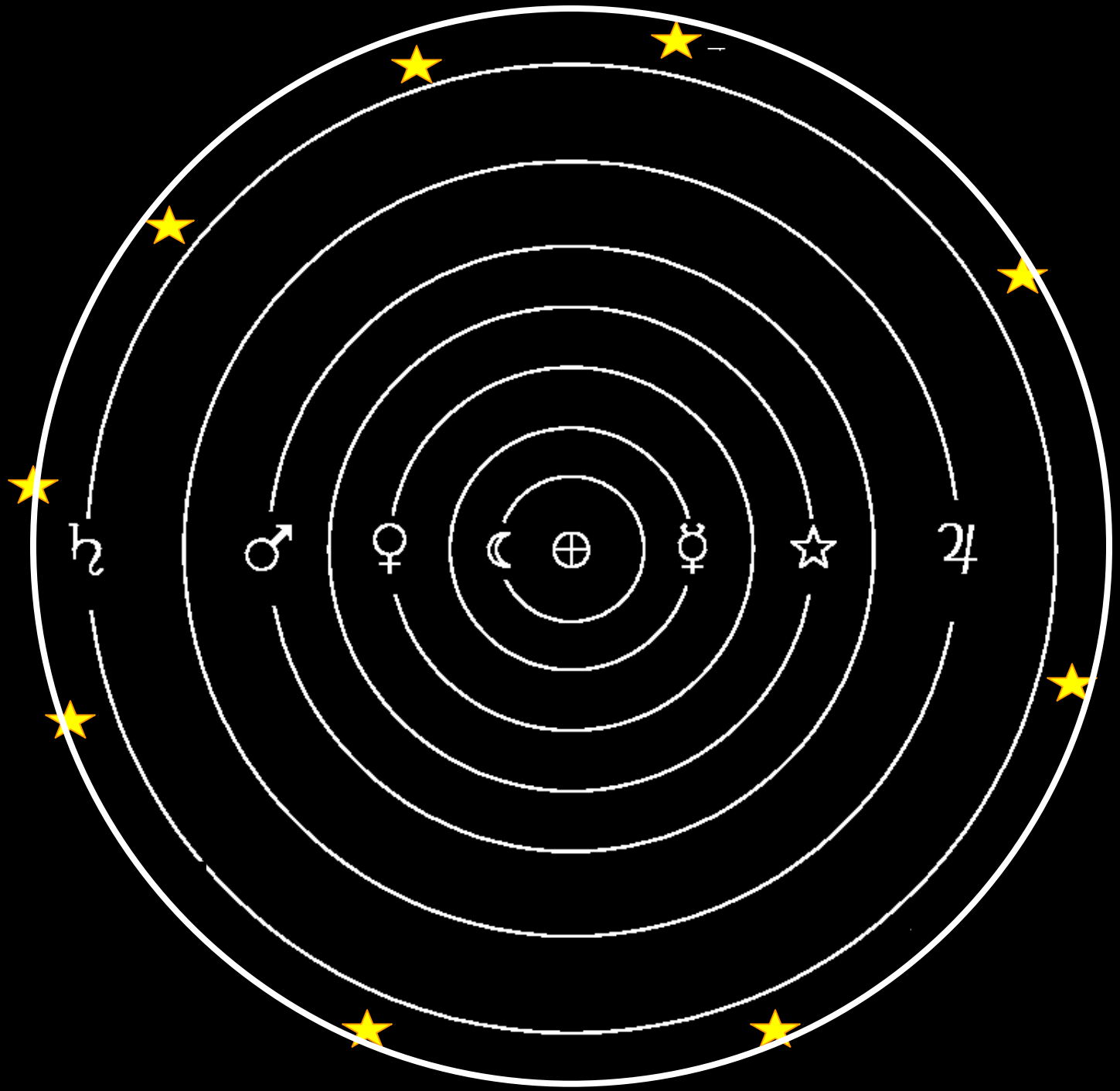


Planet Imager

Formation Flying

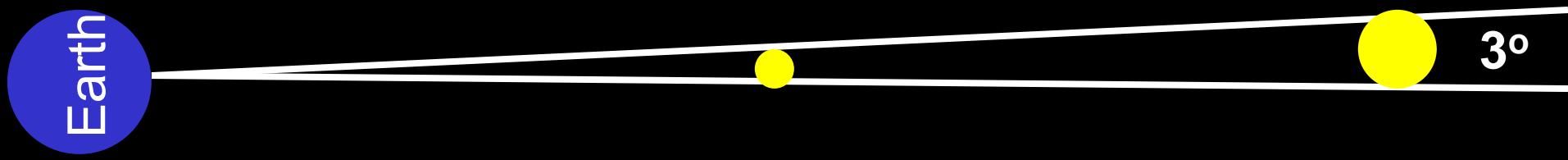
Launch: 2030

32 X 8 meter mirrors
Baseline = 6000 km



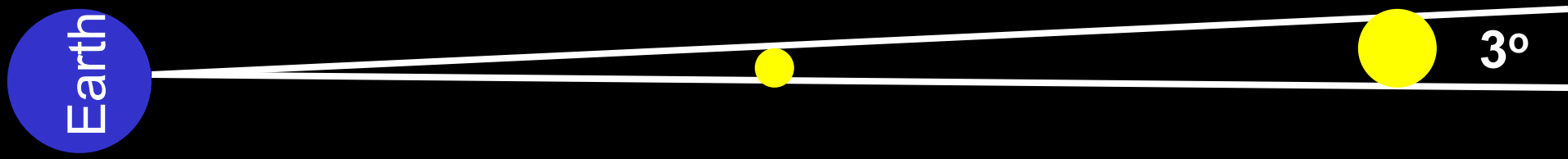
Planet	angular diameter (in minutes)	
	Ptolemy	True
Mercury	2	0.01
Venus	3	0.5
Mars	1.5	0.15
Jupiter	2.5	0.4
Saturn	1.7	0.2
Bright stars	1.5	~0

How far away are stars? How big are stars?

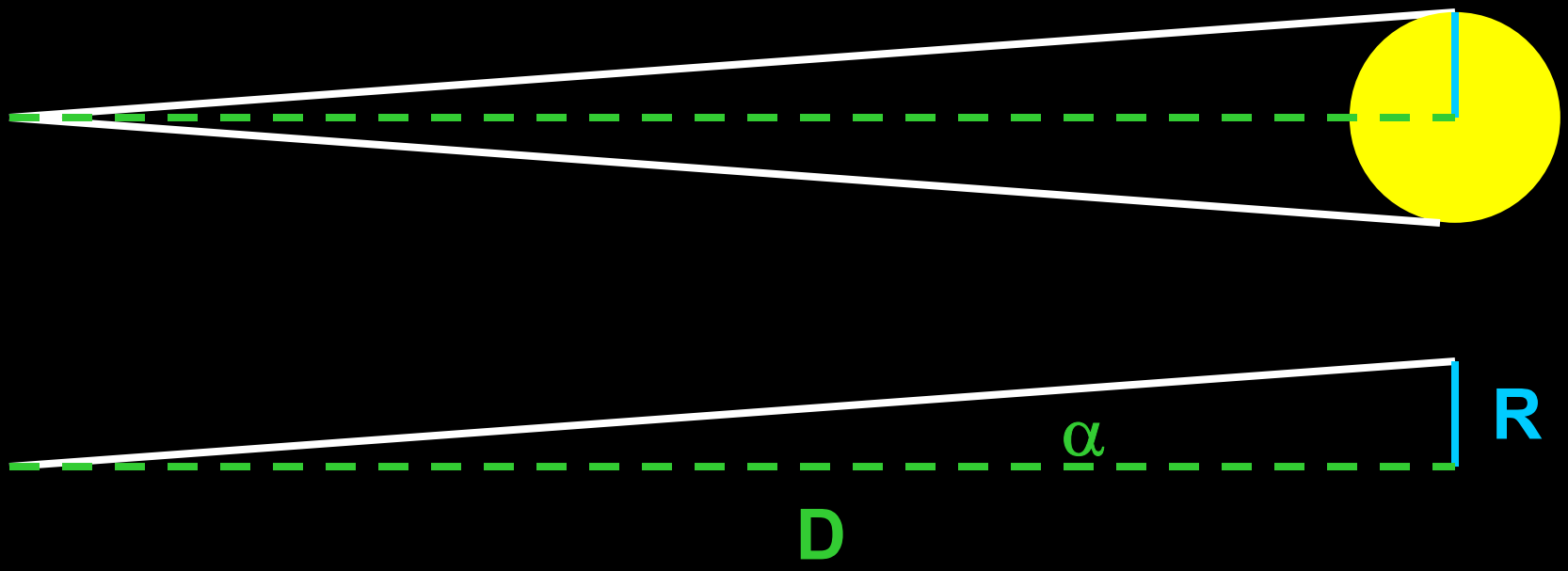


Both objects have an angular diameter of 3°

How far away are stars? How big are stars?

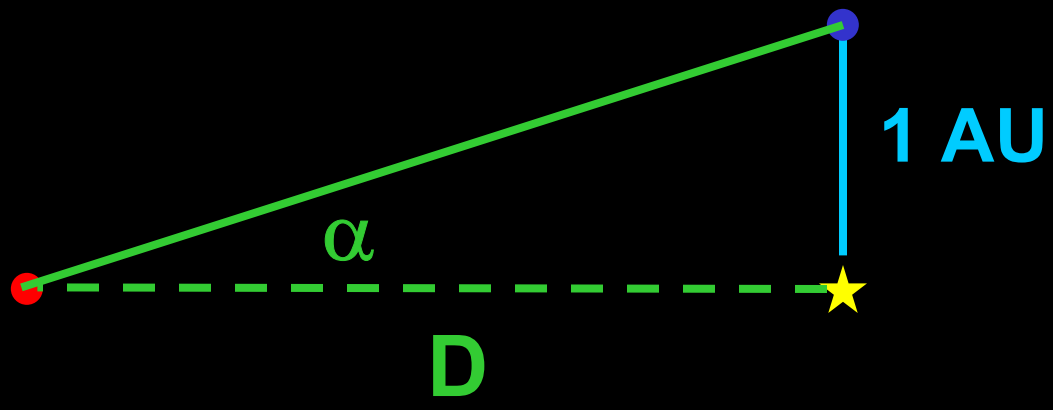


Both objects have an angular diameter of 3°



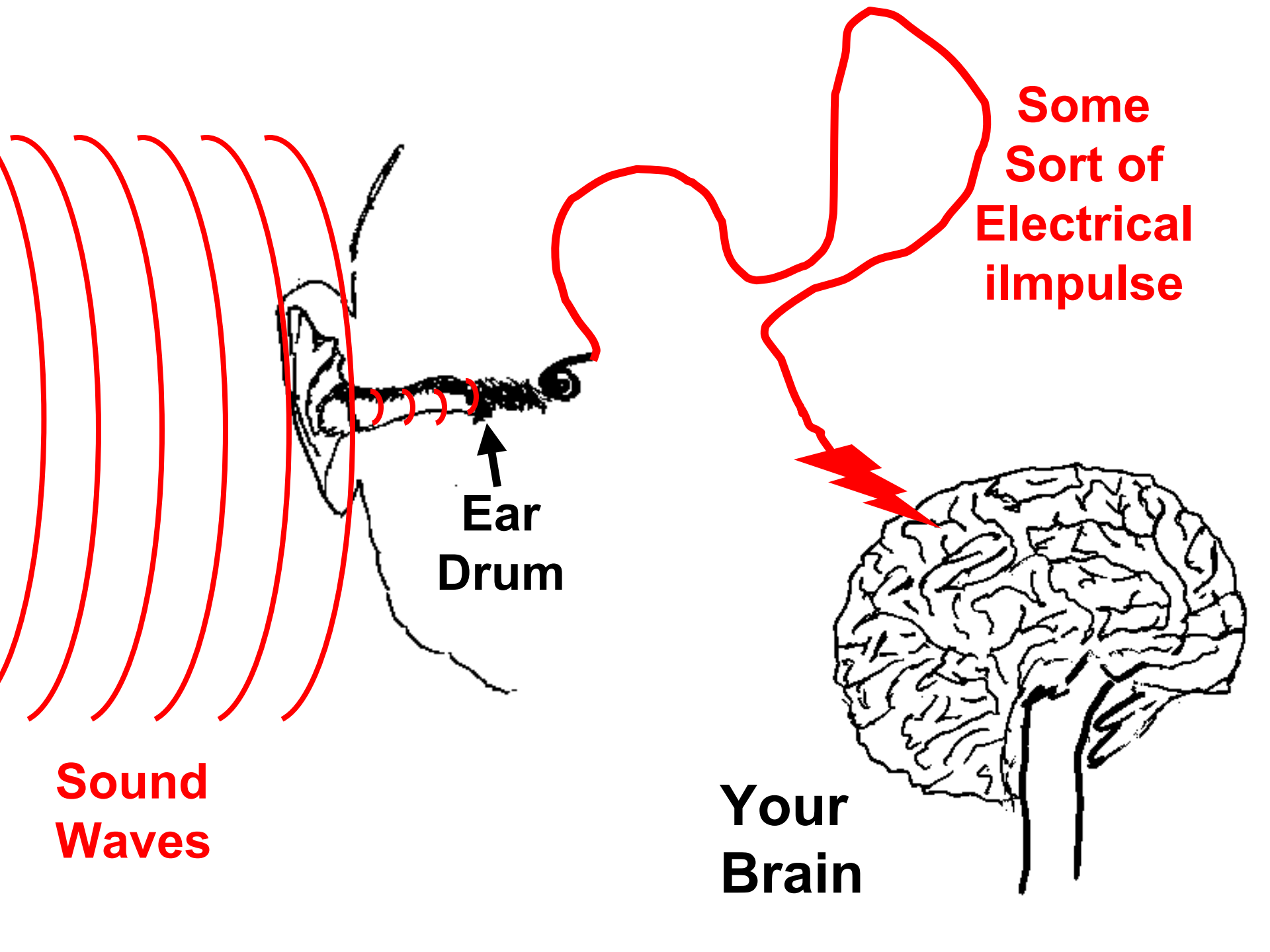
$$\frac{D}{pc} = \frac{seconds}{parallax}$$

$$\frac{D}{200{,}000\ AU} = \frac{seconds}{parallax}$$



Run 94 Col 3 Field 387

They have different apparent brightness
They have different colors
They move
They change in brightness


Some
Sort of
Electrical
ilmpulse
Ear
Drum
Sound
Waves
Your
Brain

$L_{THRESHOLD}$ = energy per second in ear at threshold of hearing

L_{PAIN} = energy per second in ear at threshold of pain

$L_{PAIN} / L_{THRESHOLD}$ = 10^{12} !!!

1 – 100 (10^2)

100 – 1,000 (10^3)

1,000 – 1,000,000 (10^6)

1,000,000 – 1,000,000,000 (10^9)

1,000,000,000 – 1,000,000,000,000 (10^{12})

I/I_0	$\log (I/ I_0)$	$dB \equiv 10 \log (I/ I_0)$
10^{-2}	-2	-20
1	0	0
10	2	20
10	6	60
10	12	120
10	20	200

Difference of about 1 dB is the smallest change that can be noticed by the human ear

Intensity: energy per time per area

$$I = \frac{\text{Energy}}{\text{Time}\ \ \text{Area}}$$

$\frac{\text{Energy}}{\text{Time}}$ can be measured in watts

Area can be measured in cm^2

Intensity in watts per cm^2

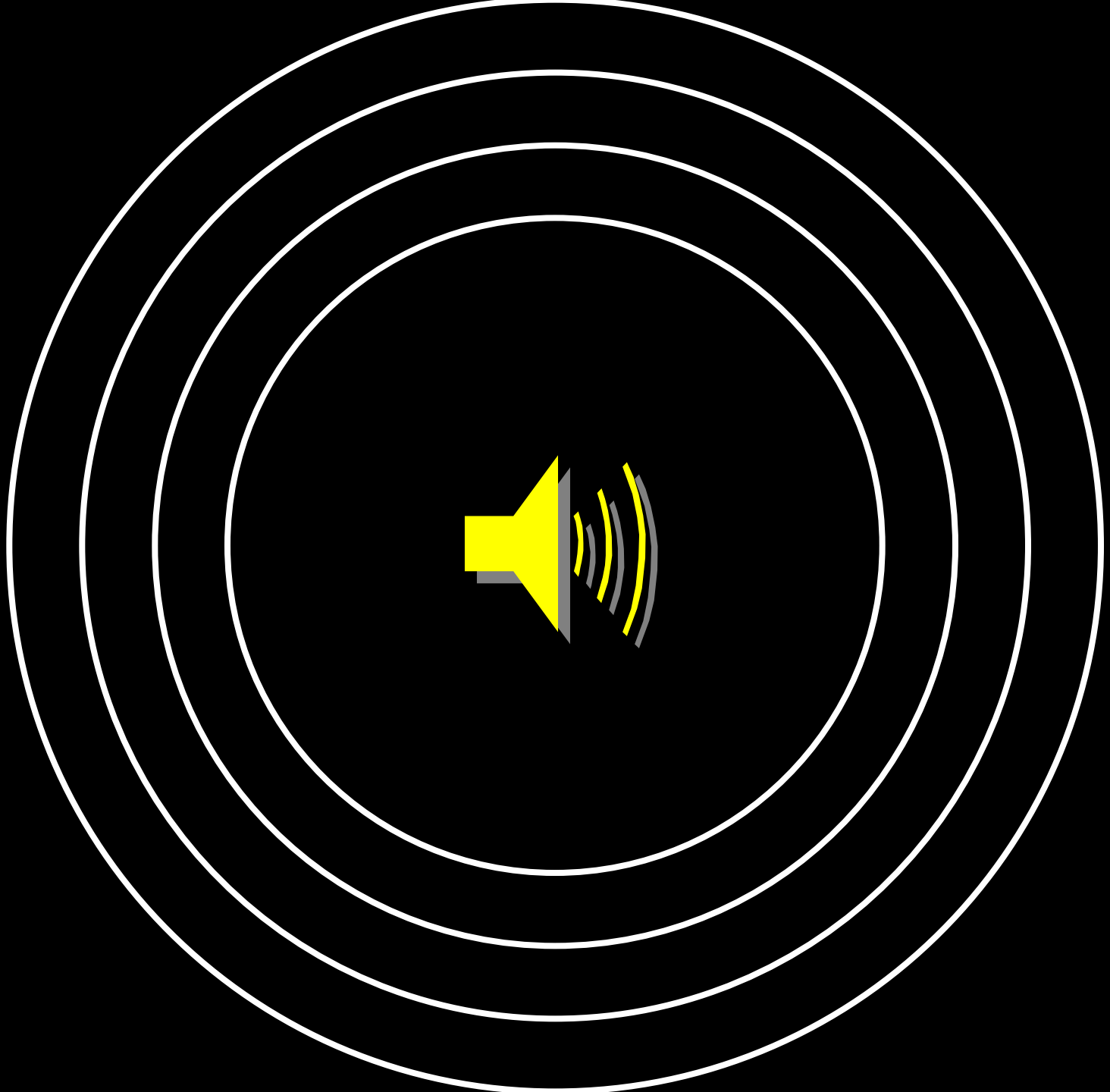
Intensity: energy per time per area

$$I = \frac{\text{watts}}{\text{cm}^2}$$

Power (watts) property of source

Intensity depends on power and distance between source and detector

$$\text{Intensity} = \frac{\text{power}}{4\pi R^2}$$



Intensity: energy per time per area

$$I = \frac{\text{Energy}}{\text{Time}\ \ \text{Area}}$$

$\frac{\text{Energy}}{\text{Time}}$ (Luminosity) can be measured in watts

Area can be measured in cm^2

Intensity in watts per cm^2

$L_{SUN} = 4X10^{26}$ W

Intensity: energy per time per area

Luminosity (watts) property of source

Intensity depends on luminosity and distance between source and detector

$$\text{Intensity} = \frac{\text{Luminosity}}{4\pi R^2}$$

LET THERE BE LIGHT!

Greeks classified stars into 6 classes, or magnitudes

Brightest stars were 1st magnitude
Dimmest stars were 6th magnitude

Eyes, like ears, are logarithmetic detectors.

Intensity of brightest stars = 100 X dimmest.

Some Magnitudes

Sun	m = – 26.8
Venus	m = – 4
Sirius	m = – 1.5
Naked eye limit	m = 6
Binoculars	m = 10
Pluto	m = 15
Large telescope (visual)	m = 20
Large telescope (photograph/ccd)	m = 25

Our Sun ain't the brightest bulb in the box!

$$L_{SIRIUS} = 25 \times L_{SUN}$$

$$\text{Intensity} = \frac{\text{Luminosity}}{4\pi R^2}$$

For stars we know distance to via parallax:

Measure Distance (R)
Measure Intensity
→ Know Luminosity

$$\frac{d}{pc} = \frac{''}{parallax}$$

star	parallax ('')	distance (pc)	apparent magnitude	luminosity (solar)
α Centauri	0.75	1.3	0	1.5
Barnard's star	0.5	2.0	9.5	0.0005
Sirius	0.4	2.5	-1.5	25
Altair	0.2	5.0	0.8	10

$$\text{Intensity} = \frac{\text{Luminosity}}{4\pi R^2}$$

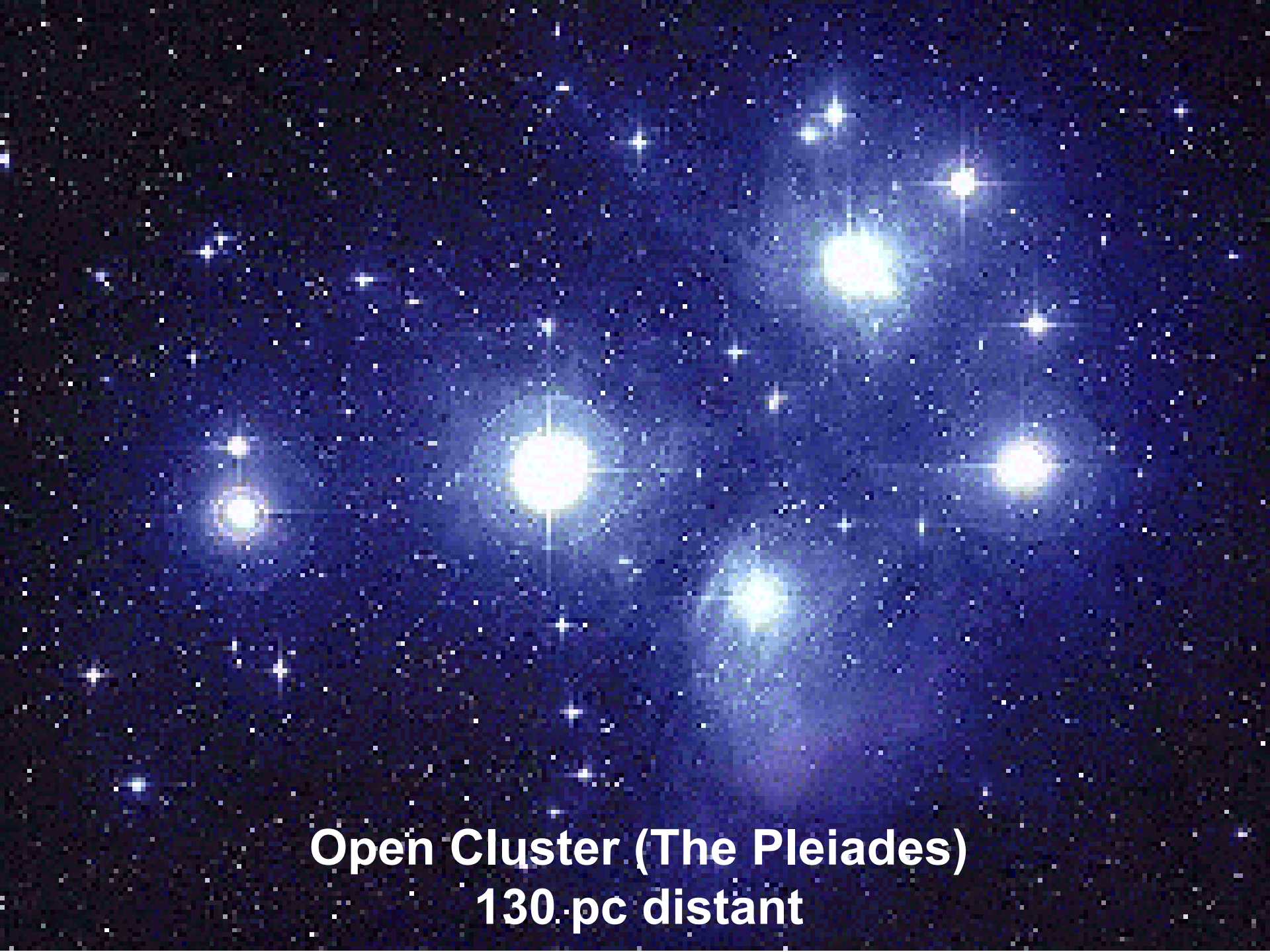
For stars we know Luminosity:

Measure Luminosity
Measure Intensity → **Know Distance**

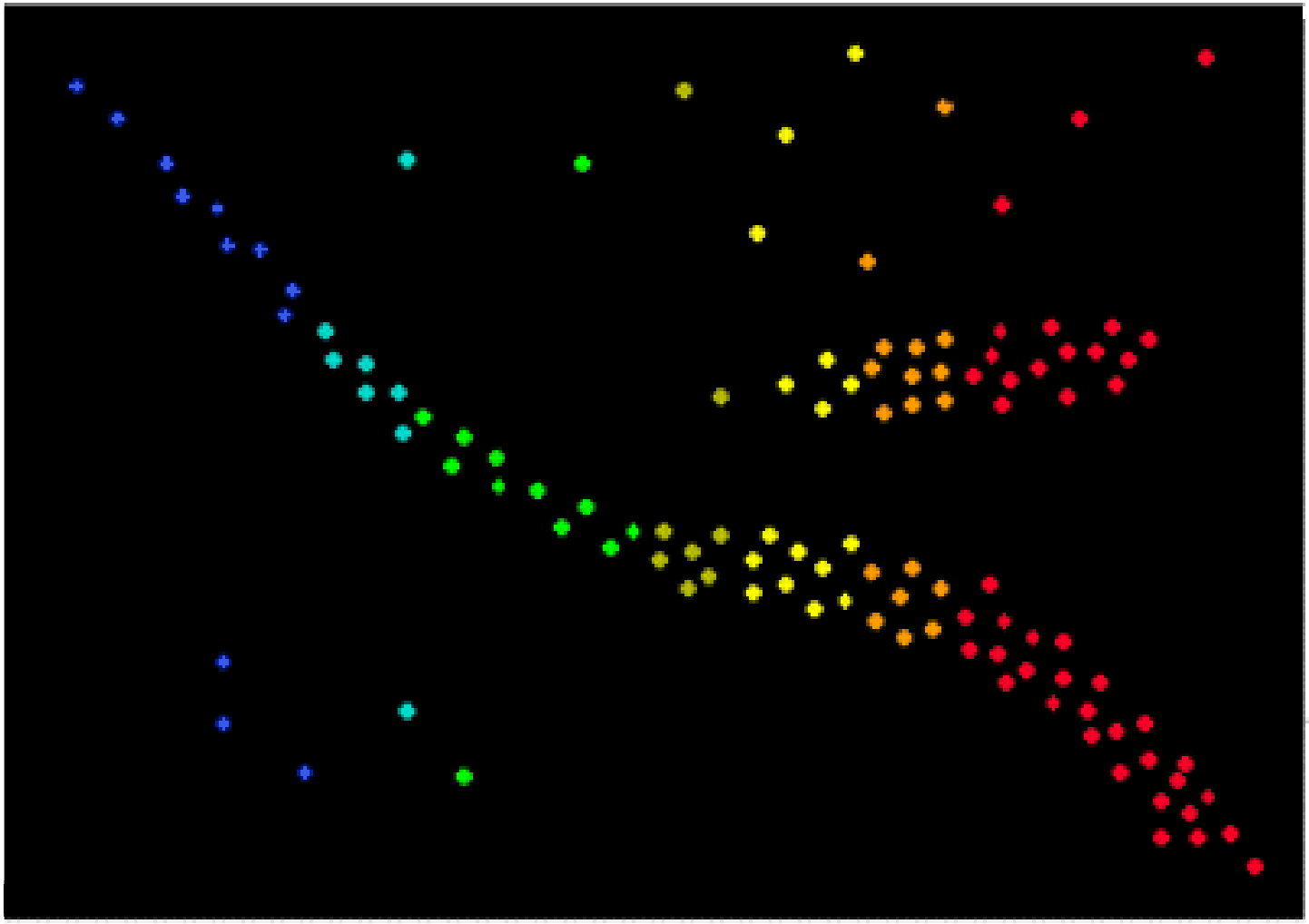
They have different colors

COLORS OF THE RAINBOW:

R O Y – G – B I V


Open Cluster (The Pleiades)
130 pc distant

Schematic Hertzsprung-Russell Diagram



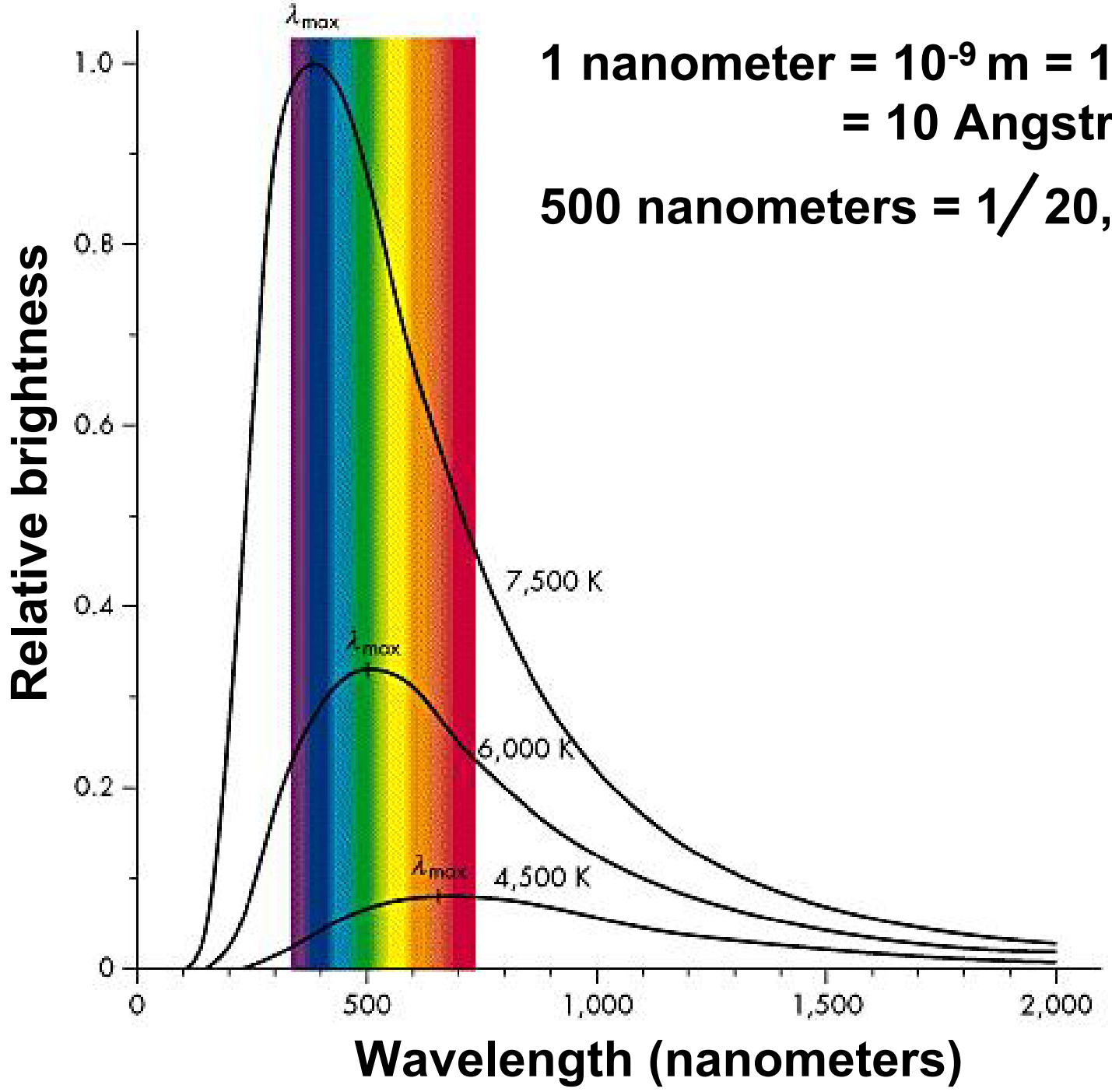
BRIGHT

MAGNITUDE

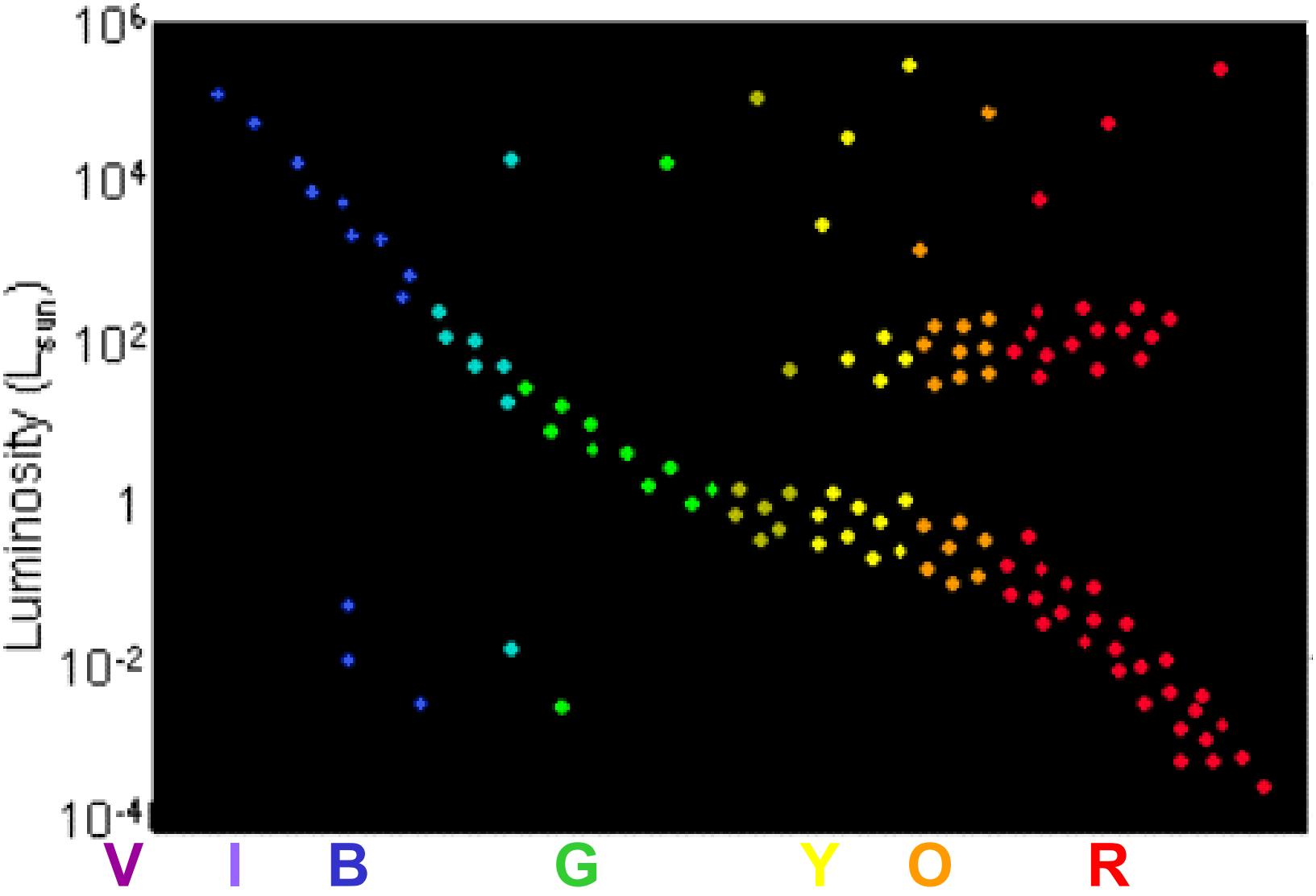
DIM

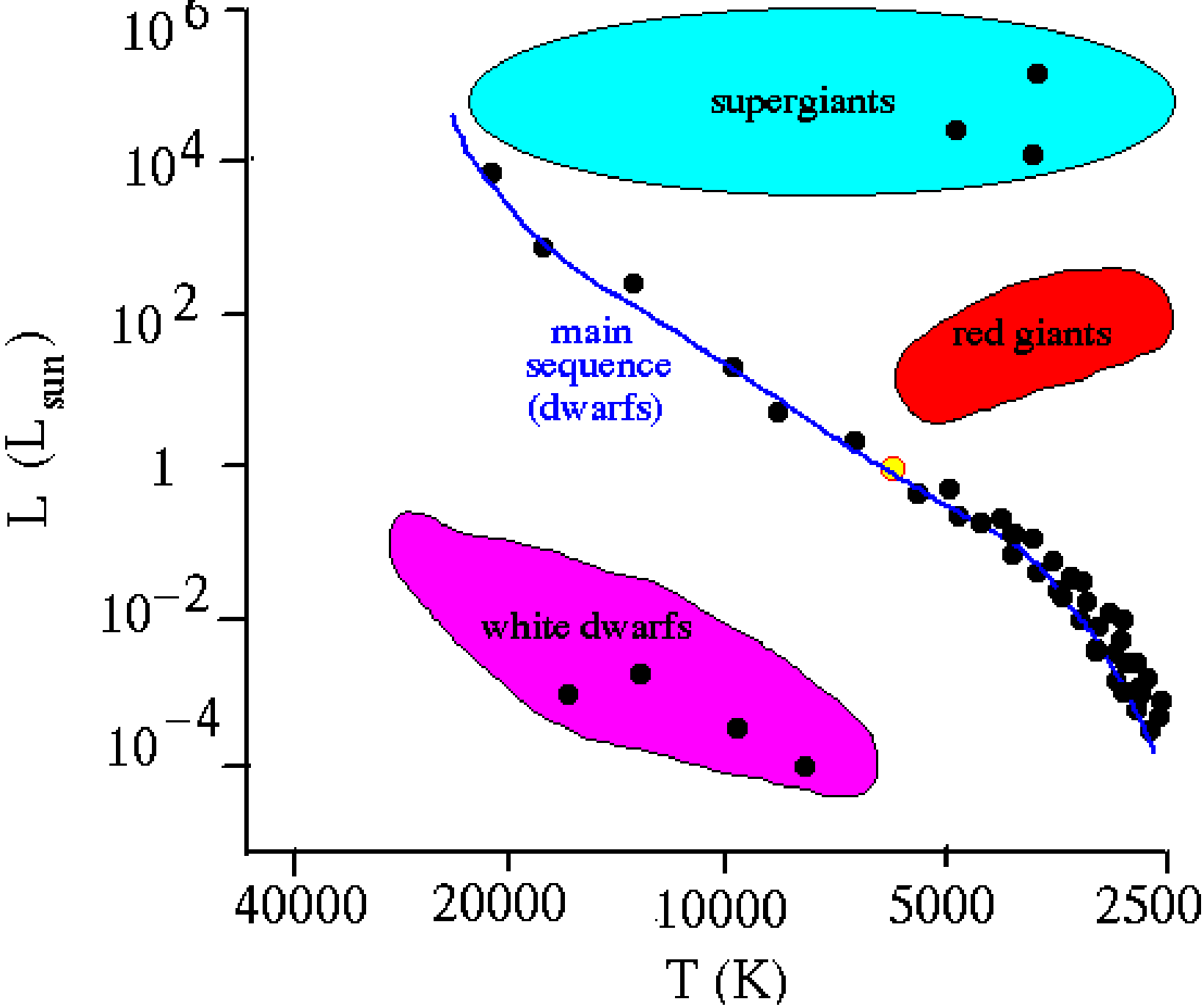
V I B G Y O R

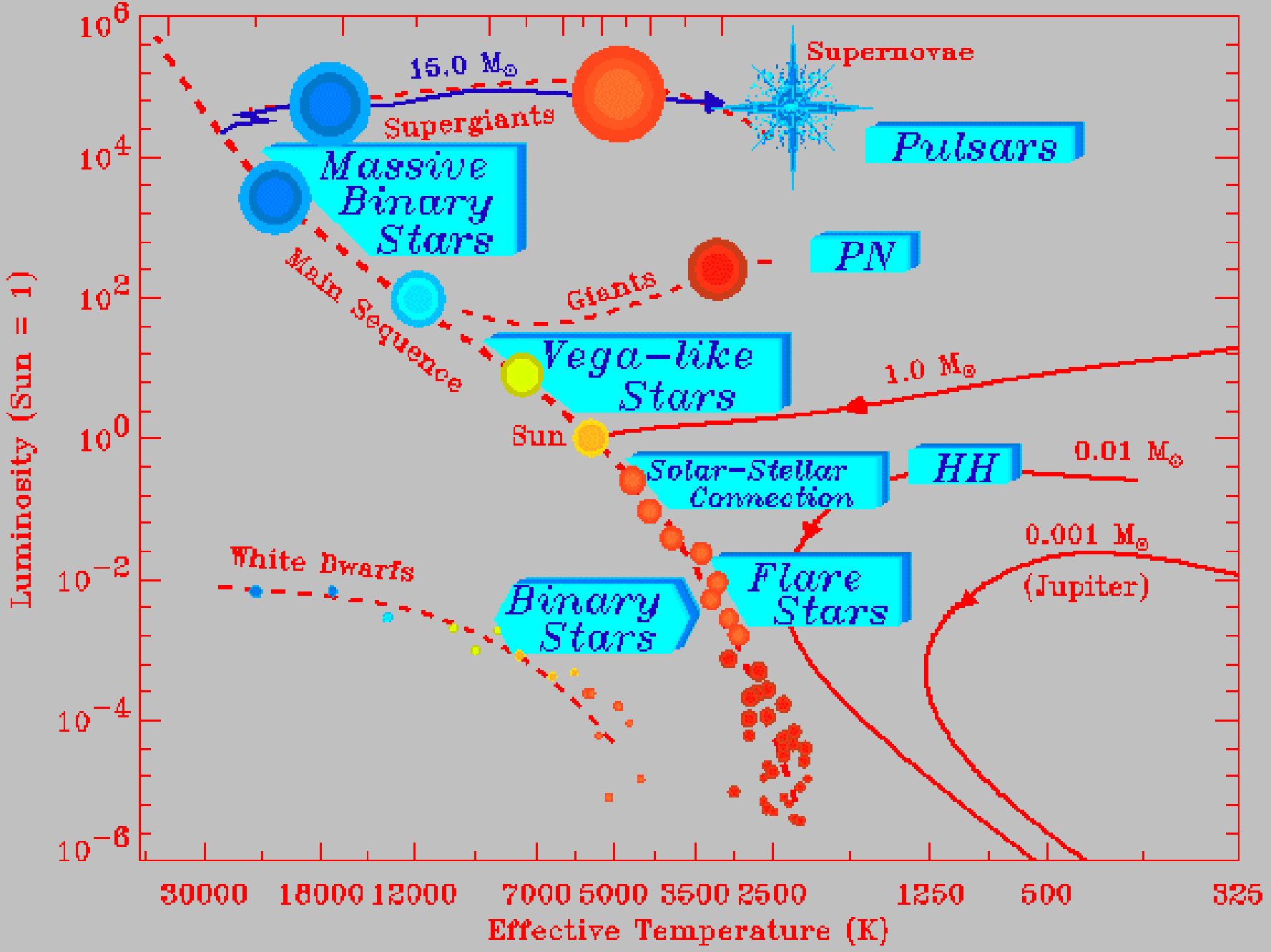
COLOR

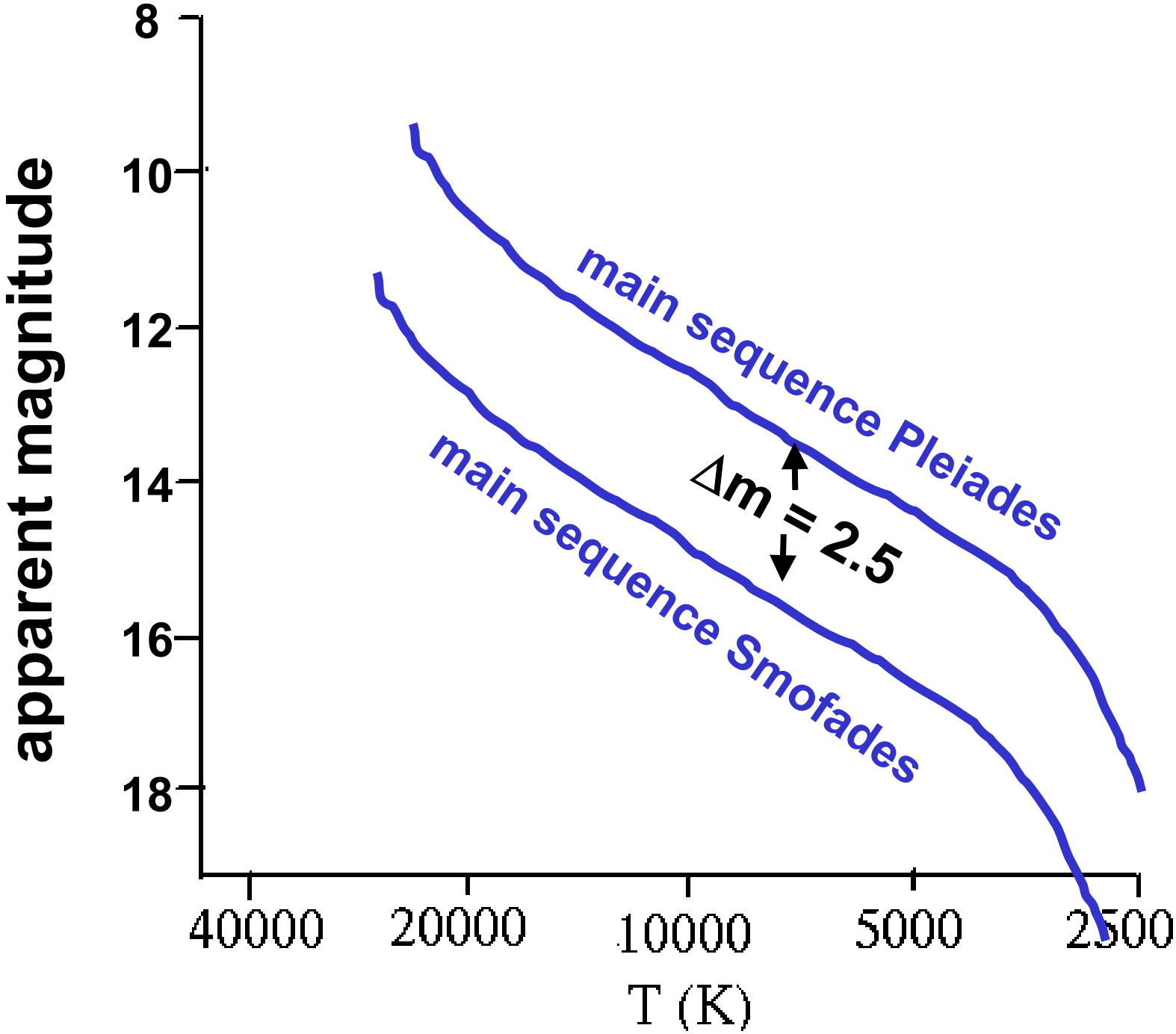

1 nanometer = 10-9 m = 10-7 cm
= 10 Angstroms
500 nanometers = 1/20,000 cm
Relative brightness
1.0
0.8
0.6
0.4
0.2
0
λmax
7,500 K
λmax
6,000 K
λmax
4,500 K
0
500
1,000
1,500
2,000
Wavelength (nanometers)

Schematic Hertzsprung-Russell Diagram




10^6
10^4
10^2
1
10^{-2}
10^{-4}
L (L_{sun})
supergiants
red giants
main
sequence
(dwarfs)
white dwarfs
40000
20000
10000
5000
2500
T (K)


Luminosity (Sun = 1)
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
15.0 $M_\odot$
Supergiants
Supernovae
Pulsars
Massive Binary Stars
PN
Giants
Main Sequence
Vega-like Stars
1.0 $M_\odot$
Sun
Solar-Stellar Connection
HH
0.01 $M_\odot$
0.001 $M_\odot$
(Jupiter)
White Dwarfs
Binary Stars
Flare Stars
30000
18000
12000
7000
5000
3500
2500
1250
500
325
Effective Temperature (K)


apparent magnitude
8
10
12
14
16
18
main sequence Pleiades
main sequence Smofades
Δm = 2.5
40000
20000
10000
5000
2500
T (K)